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AQS-20 Through-The-Sensor Environmental Data Sharing

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ABSTRACT

The Naval Research Laboratory (NRL) has developed an advanced architecture for connecting many maturing Through-The-Sensor (TTS) efforts for an end-to-end demonstration using the AQS-20 mine hunting sensor. The goal of TTS technologies is to exploit tactical sensors to characterize the battlespace environment for Navy Fleet Tactical Decision Aids (TDAs) with minimal impact on tactical systems. The AQS-20 Rapid Transition Process (RTP) will utilize the AQS-20 to demonstrate sensor data collection, processing, fusion, storage, distribution and use in a tactical decision aid. In recent years, NRL has shown that the AQS-20 can be used to obtain swath bathymetry and bottom sediment information in a single flight. In the AQS-20 RTP, these data will be processed and fused with historical databases to provide an improved environmental picture. The RTP will also utilize the Geophysical Data Base Variable resolution (GDBV) dynamic format for storing local datasets. The GDBV dynamic has been developed in prior years to provide an extensible, efficient data storage format for TTS systems. To provide the interconnectivity that is critical to Network Centric Warfare (NCW), the GDBV will be connected to the SPAWAR funded Tactical Environmental Data Services (TEDServices). To complete the flow of information from sensor to user, the RTP will transmit information to the MEDAL TDA through existing connections in The Naval Oceanographic Office's (NAVOCEANO) Bottom Mapping Workstation (BMW). In addition, TEDServices will handle transmission of the AQS-20 data to NAVOCEANO who serves as the domain authority for oceanographic datasets in the U.S. Navy.

Keywords: AQS-20, TTS, SPAWAR, RTP, NCW, BMW, NAVOCEANO, TEDServices, GDBV, NRL

1. INTRODUCTION

In recent years, the Naval Research Laboratory (NRL) has developed several state-of-the-art systems that support the Through-The-Sensor (TTS) concept. The TTS paradigm focuses on the "use of any organic Naval sensor to either directly measure or infer specific MetOc [Meteorology and Oceanography] parameters."[8] In general, TTS techniques are motivated by the desire to provide near real-time feedback to sensors, Tactical Decision Aids (TDAs), and models. Properly designed TTS systems facilitate the optimization of sensor performance, on-scene alteration of tactics and plans, battle group pre-positioning in near real-time, and long term updates of the Navy standard databases on a global scale.[8] TTS implementations must be minimally intrusive to the combat system and not interfere with the primary mission, safety, or vulnerability of the platform. To this end, NRL is developing techniques that exploit the data stream from tactical systems to extract ocean environmental measurements.[3]

The Space and Naval Warfare Systems (SPAWAR) sponsored AQS-20 Rapid Transition Process (RTP) is a substantial effort that seeks to interconnect several NRL-developed, TTS systems and existing NAVOCEANO, operational Mine Warfare (MIW) systems into an efficient, cohesive architecture, called SEAfloor and Bathymetric Environment Data (SeaBED). Being the first end-to-end demonstration of TTS technologies, the AQS-20 RTP will provide a valuable architecture for follow-on developments that utilize TTS systems. The end goal of the RTP is to import fused datasets into the MEDAL Tactical Decision Aid (TDA). The fused datasets are generated in the SeaBED software by merging supplemental (AQS-20 derived) and historical (official NAVOCEANO) datasets using experimental and approved fusion techniques.

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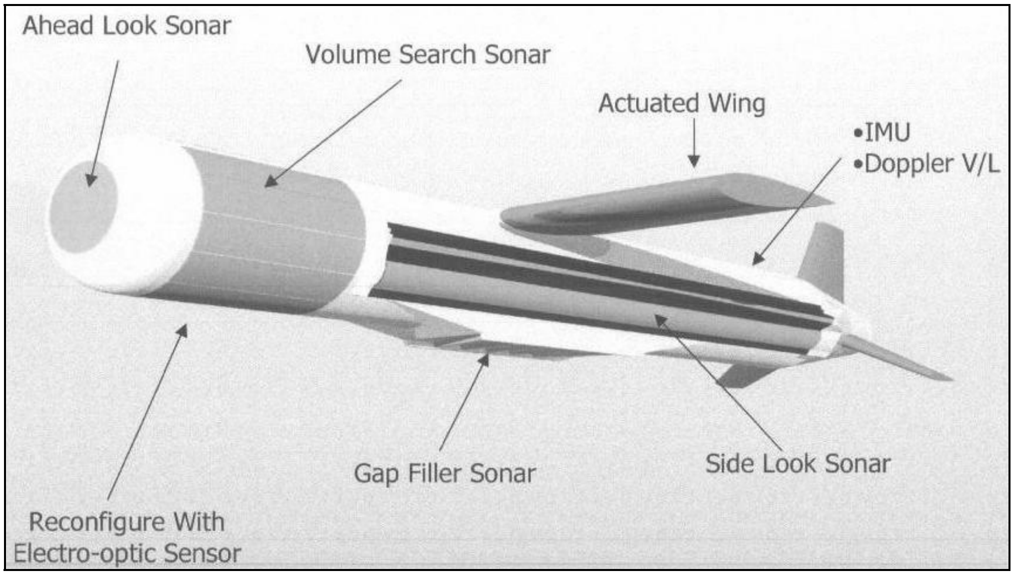

Fig. 1 The AQS-20 Sonar System

Shown in Fig. 1, the AQS-20 is an airborne, variable depth, mine hunting sonar system designed to detect, classify, and identify moored and bottom mines using side-scan, forward-looking, and volume-search sonar systems from deep water to very shallow.[5] The sonar pod is towed in a reconnaissance mode by the AN/WLD-1 Remote Minehunting System miles ahead of the battle group, and in an area search mode by the MH-60 helicopter.[9] The AQS-20 is currently towed by a MH-53 helicopter with plans to be towed by the MH-60 in the future. AN/WLD-1 is an unmanned diesel powered, semi-submersible vehicle designed for use from surface combatants.[4] The CH-60 will conduct mine countermeasures from air-capable U. S. Navy ships.

The SeaBED architecture is a centralized system that can be interactively managed using the SeaBED Data Manager (SeaBED DM) application. The connectivity of these systems facilitates data sharing at the sensor, local, and global levels in near real-time. Global connectivity is achieved through the use of the SPAWAR-sponsored, Tactical Environmental Data Services (TEDSerivces). By using TEDServices, the SeaBED architecture can connect to other survey platforms and to the environmental domain authority, NAVOCEANO, using advanced subscriptions services and dynamic connectivity.[13] In this paper, the overall data flow of the AQS-20 RTP will be described with particular emphasis on the data sharing capabilities.

2. RTP OVERVIEW

The primary motivation of the AQS-20 RTP is to successfully demonstrate the inner-operability of several NRL developments that support the TTS concept. Under the sponsorship of SPAWAR PMW 180, TTS environmental data collection using the AQS-20 was demonstrated.[6] In this highly successful venture, NRL developed algorithms that extract swath bathymetry and sediment profile information from a single flight of the new AQS-20 mine hunting sensor.[9] It is important to note that the data collected in this program met or exceeded official MIW requirements for bathymetry and doctrinal sediment type.[6] As shown in Fig. 2, the AQS-20 sensor is the sole source for in-situ environmental data in the AQS-20 RTP. However, through its generic design and carefully planned extensibility, the SeaBED system can be easily extended to work with other sensors that produce bathymetry or sediment profile information.

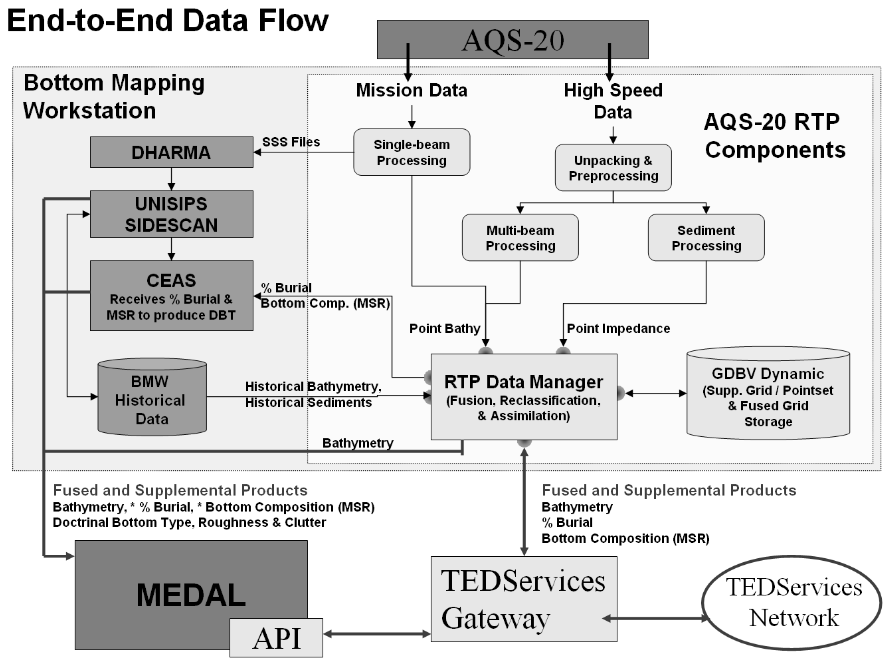

Fig. 2 AQS-20 RTP Data Flow Diagram.

The NAVOCEANO Bottom Mapping Workstation (BMW) is the host for the AQS-20 RTP. The BMW is a Linux-based, ruggedized system that is utilized by NAVOCEANO for near real-time ocean bottom surveys. A standard BMW configuration is shown in Fig. 3. In the AQS-20 RTP, the BMW hosts the SeaBED Data Manager, AQS-20 processing software, UNISIPS (for side scan imagery processing), DHARMA, and GDBV-D related software.

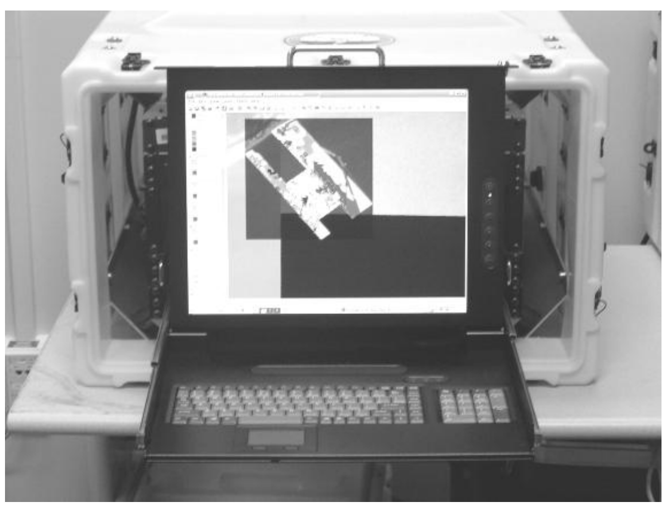

Fig. 3 A Standard BMW System

GDBV-D is a dynamic database that was originally developed to support the SPAWAR-funded GeoAcoustic Inversion Toolkit (GAIT). GDBV-D is a modern, object-oriented database that is implemented entirely in the Java Programming Language.[10] This dynamic database compliments the GDBV Historical database that is slated to replace the Oceanographic and Atmospheric Master Library (OAML) ocean bottom databases in the near future. The GDBV-D is an extensible version of the OAML GDBV that contains generic data objects for storing any type of environmental data. Both the OAML GDBV and the GDBV-D use the same APIs for accessing the datasets stored in a hierarchical data model.[11] In the SeaBED software, GDBV-D fulfills the role of local dataset repository for all supplemental, historical, and fused datasets. Building a local database simplifies the input / output operations in the various SeaBED algorithms since they need only deal with a single database format vise several independent database/file formats.

TEDServices will be used to distribute fused and supplemental data from the local GDBV-D to local and remote TDAs via the SeaBED DM. During numerous FY03 and FY04 exercises, TEDServices, which is the primary Fleet repository and source of MetOc data, successfully demonstrated two-way connectivity between data production centers and fleet units. This new technology provides environmental data via subscriptions and is designed to ensure a common, current environmental view while minimizing bandwidth limitations.[13]

The SeaBED system includes advanced data fusion algorithms that facilitate the merging of historical and supplemental datasets into a new improved ocean bottom view. Currently, two fusion algorithms are integrated into the SeaBED DM: the OAML Feathering Algorithm and a new NRL kriging algorithm. The OAML Feathering Algorithm is two-dimensional interpolation algorithm that is incorporated into the NAVOCEANO Digital Bathymetric Data Base – Variable resolution (DBDB-V) APIs for merging supplemental datasets from the PUMA system with historical DBDB-V grids.[12] The new NRL kriging algorithm is a unique approach to the fusion problem that uses a statistical kriging and provides several parameters for customization.

MEDAL is the sole MIW planning tool that is used in the Navy today. With respect to the AQS-20 RTP, it is the ultimate destination of supplemental and fused products that are produced by the SeaBED software.

The SeaBED system demonstrates the vast possibilities of TTS systems by connecting several bottom mapping applications to form a cohesive architecture. As shown in Fig. 2, the data flow between the interconnected systems begins with a link between the sensor and the RAID device. Then, the data is processed and stored in the GDBV-D on the BMW platform. The BMW is then connected to a MEDAL system and TEDServices Gateway Server demonstrating external connectivity at the local (survey platform) and global (domain authorities and other survey platforms) scale, respectively.

3. SEABED DATA MANAGER

In the early stages of the SeaBED software development, NRL recognized that a central management application is critical for connecting and managing the many systems proposed in the AQS-20 RTP. This application, named the SeaBED Data Manager (SeaBED DM) provides a Graphic User Interface (GUI) based management interface for interactive control of the SeaBED system. The SeaBED DM allows the user to process raw data by executing the AQS-20 data processing software directly from intuitive menu systems. Additionally, the SeaBED DM will read historical datasets in the NAVOCEANO file formats (e.g. MEDAL CHRTR, xyz, etc.) that are stored on the BMW.

The SeaBED DM uses the GDBV-D as a local data store for supplemental, historical, and fused datasets. The GUI provides a tab-based view of the GDBV-D database with individual tabs for supplemental, historical, and fused datasets. Within each tab pane, a tree view of the datasets is shown in which the datasets are grouped by their respective data types. This logical view of the GDBV-D database gives a user the ability to quickly determine the contents of the SeaBED data repository. Moreover, from the SeaBED DM, the user can create, edit, and view associated metadata for each dataset. This metadata is stored along with the dataset in the local GDBV-D and allows the user to record a wide variety of information as string objects.

From the SeaBED DM the user can convert a dataset containing NAVOCEANO's HFEVA32 bottom sediment category codes into impedance values for subsequent fusion with supplemental AQS-20 bottom profile datasets. For example, after a user ingests a historical HFEVA32 dataset, they can convert the datasets into impedance values and then fuse it with a supplemental impedance dataset that was generated from AQS-20 raw data.

Users can also use the visualization capabilities of the SeaBED DM to plot datasets for an expedient quality check. All the supported data types can be viewed in two-dimensions with color-filling using the SeaBED DM. Within the visualization frame (see Fig. 4), the user can modify the color scale and depth range on impedance or bathymetric plots. If a NAVOCEANO bottom type data type is visualized, the user will see the official color schemes used by

NAVOCEANO. A user can also generate an overlay plot in which he or she can display a set of points over a grid. The overlay plot feature is useful for comparing supplemental datasets with historical or fused grids. Using the overlay plot feature, the user can assess the level of agreement between supplemental and historical and/or the supplemental and fused datasets.

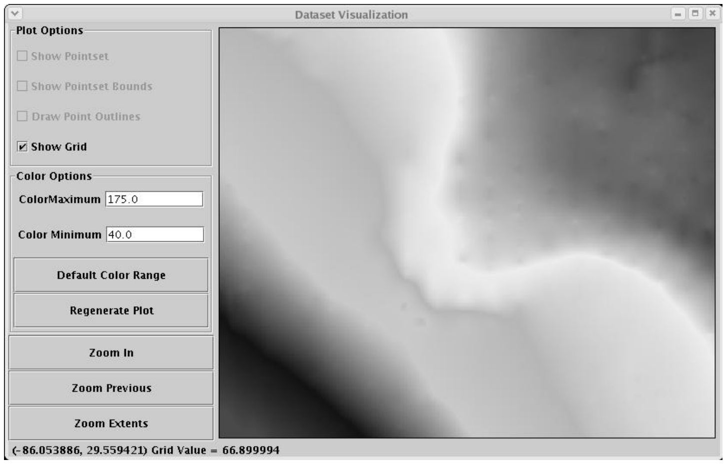

Fig. 4 Example of Visualization Capabilities in SeaBED DM

The AQS-20 RTP data fusion algorithms are controlled and executed from within the SeaBED DM. Each data fusion algorithm used in the RTP offers "tweaking" parameters that control optional smoothing techniques and algorithm speed of execution. These parameters can be set through dialog boxes that are customized for each data fusion algorithm.

The SeaBED DM allows the user to export and import data from the supported NAVOCEANO MIW file formats. The formats that are supported for importation into the local GDBV-D are CHRTR (binary grid format), MEDAL CHRTR (binary grid format with special MEDAL header), and xyz (or yxz) ASCII files. The supported export formats are CHRTR, MEDAL CHRTR, xyz (or yxz) ASCII, MEDAL Soundings, GRASS GIS ASCII, and Shapefile.

The SeaBED DM controls all communications between the BMW and the TEDServices Gateways. From the SeaBED DM the user can submit files (any format) to a particular TEDServices Gateway. Also, the user can retrieve data from a TEDServices Gateway Virtual Natural Environment (VNE) as a 3D Grid object. The SeaBED DM also allows the user to create a data order on a TEDServices Gateway forcing it to execute automatic subscriptions to a particular data type on another TEDServices Gateway. The data order feature is used to receive grids that are placed on the NAVOCEANO TEDServices Gateway automatically.

Although some features of the SeaBED DM are specific to the AQS-20 sensor, NRL has invested a substantial amount of effort into maintaining a generic and flexible interface to the application for possible future expansion to support other TTS systems. Since the application will import point ASCII files and it exports fused grids in a standard file formats, it is straightforward to use this application with other TTS systems. Furthermore, the connectivity with TEDServices provides Network Centric Warfare (NCW) capabilities regardless of the source sensor or data type. The SeaBED DM could also be extended to include the functionality of some of the external systems to reduce the number of outside components in the system. By including features such as Doctrinal Bottom Type (DBT) calculation, the SeaBED DM could pay a bigger role in the RTP process and also provide a second look at some of these complex processes for quality assurance concerns.

4. AQS-20 DATA PROCESSING

Derived from the original program to extract bathymetry from the AQS-20 sensor, the data processing software has been modified to be more robust, run faster and provide final data products that are suitable to subsequent ingest into the local GDBV-D and remote improvements by NAVOCEANO scientists. The data processing is segmented into two primary categories based on the data types available from mission data and high speed data. The mission data is recorded on the main mission recorder called the Mass Memory Unit (MMU) while the high speed data is recorded on a special High Speed Recorder (HSR) device that is not always available.[7] By using two processing streams, all of the data available from the AQS-20 sonar can be exploited when it transitions into operation use.

Since the HSR records the full dynamic range and resolution from the sonar, these data represent the most valuable information of the two processing streams. From the HSR stream, all the information necessary for reconstructing multibeam bathymetry and doctrinal bottom composition is available. If the scenario arises where the HSR is not available for a particular operation, the MMU data can be utilized to provide single beam bathymetry and side scan sonar (SSS) images for most operational modes of the AQS-20 sonar system.[7]

For the planned AQS-20 RTP demonstrations, a HSR will be available, ensuring access to both data streams for testing. In Fig. 5, the data processing flow is depicted graphically. In the data processing stage, data sources from the AQS-20 will be connected to the workstation computer and accessed directly.

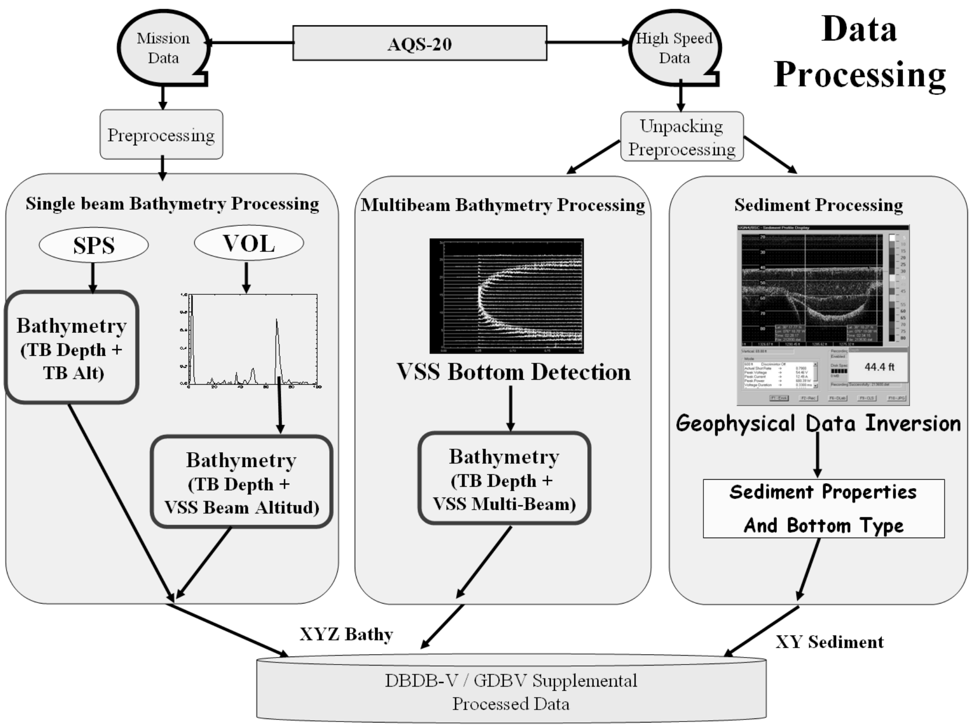

Fig. 5 Notional View of AQS-20 Data Processing

Volume Search Sonar (VSS) data will be extracted from the HSR and processed separately for multibeam bathymetry and bottom sediment properties. A total of 26 beams (13 fore and 13 aft) are processed in the multibeam bathymetry solution and stored in the database as bathymetry soundings. The sediment processing uses the two most downward looking beams and solves for the bottom composition.[7] After processing is complete, bathymetry and bottom composition datasets are stored in the GDBV-D supplemental data layer via the SeaBED DM. Once in the SeaBED DM, these datasets can be fused with other datasets, prepared for use in different bottom analysis applications, and exported to local and/or remote platforms.

The MMU data will be tested using a similar processing flow. In this case, any of the bottom following modes or the volume search operation mode of the AQS-20 sensor can be used for obtaining bathymetry. However, only single beam bathymetry is available due to the limitations of the recorded data.[7] The bathymetry soundings are stored in the local GDBV-D and can be manipulated or exported in the SeaBED DM the same as the VSS datasets.

In previous work, it has been determined that the data accuracy will meet or exceed MIW requirements in most cases.[1] Limitations on the accuracy of the bathymetric data appear to be related to the resolution and bias of the pressure sensor used for determining the towbody depth.[2]

5. LOCAL CONNECTIVITY

After AQS-20 data processing, the resulting datasets are ingested into the SeaBED DM for subsequent manipulation and data fusion with historical datasets from the BMW. To facilitate the fusion of supplemental datasets with historical datasets, the SeaBED DM provides the capabilities to populate the local GDBV-D via its connection to the BMW local historical data repository. As shown in Fig. 6, the SeaBED system has several local connections with applications that reside on the BMW platform. SSS imagery files that are produced in the data processing phase are formatted for direct import into the UNISIPS SSS analysis suite. In UNISIPS, the SSS files are viewed and MIW roughness and clutter files are produced. These datasets are formatted into the CEAS shapefile format specification.

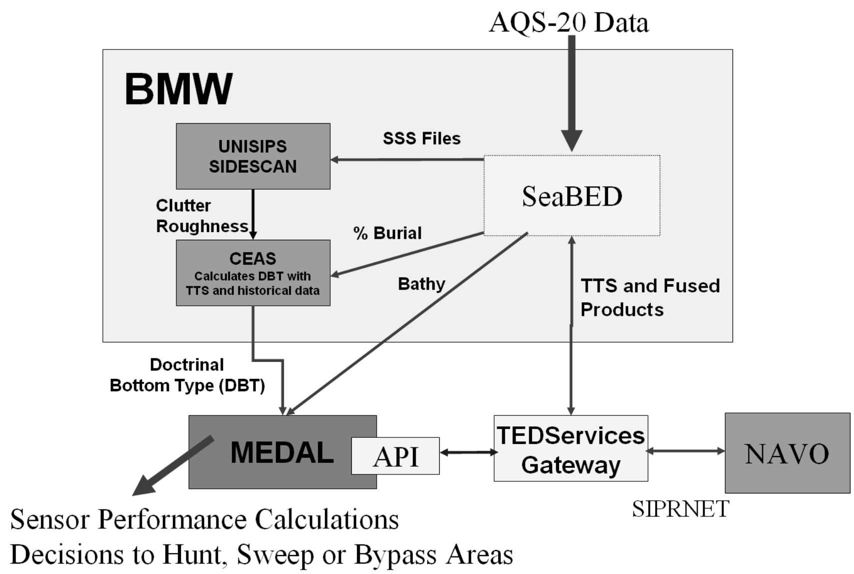

Fig. 6 SeaBED Local and Remote Connectivity

In the SeaBED DM, historical and supplemental bathymetric and sediment datasets are fused to generate fused bathymetry and MIW bottom information grids. The fused bathymetry grids can be exported to the MEDAL CHRTR file format specification from the SeaBED. Additionally, the supplemental bathymetry points can be exported to the MEDAL Soundings file format. Once exported to the local file system, the bathymetric files can be retrieved via MEDAL file transfer protocol (ftp) mechanism and imported into the MEDAL Environmental database.

Like the MIW roughness and clutter files exported from UNISIPS, the bottom information grids are exported to the CEAS shapefile specification as polygons (areas). The GRASS GIS application suite is employed behind the scenes by the SeaBED DM to generate the necessary shapefiles. Once the shapefile-formatted files are written to disk, the file header is modified to conform to the CEAS specification.

The roughness and clutter datasets from UNISIPS are imported into CEAS along with the bottom information shapefile created by the SeaBED DM. To determine the Doctrinal Bottom Type (DBT), CEAS applies standard map algebra operations on the datasets using NAVOCEANO defined standard relationships and the DBT file is exported in a Shapefile that conforms to the MEDAL specification. With the DBT file on the local file system, the MEDAL ftp mechanism is then used to import the DBT dataset into the MEDAL Environmental database. MEDAL can then use the supplemental and fused information retrieved from the SeaBED/BMW system to determine the maximum achievable "percent clearance" for a mine-hunting operation based on the percentage of undetectable mines.

The MEDAL and CEAS applications do not reside on the BMW platform. Instead these applications are installed on separate computers that are connected with the BMW through a Local Area Network (LAN). The LAN and the format compatibility with MEDAL and CEAS facilitate a seamless flow of data between the SeaBED system and the various processing applications.

6. REMOTE CONNECTIVITY

CEAS and MEDAL are connected to the SeaBED and BMW applications through a LAN for the survey platform. Most of the connectivity on the survey platform is made possible through standard network communication methods, in this case SPIRNET. Through its connectivity with a local TEDServices Gateway, the SeaBED system has the ability to connect with other platforms or the domain authority, NAVOCEANO. Using the SeaBED DM, the user can submit raw GSF files that contain unedited bathymetry to the TEDServices Gateway. NAVOCEANO can extract these files remotely with simple command line tools that communicate with the TEDServices Gateway and add value to the raw datasets using NAVOCEANO standard applications. The NAVOCEANO "value-added" process may include: dataset cleaning, more thorough tide corrections, grid generation from a dense set of soundings, and additional fusion of additional high-resolution, bathymetric datasets.

After NAVOCEANO has finished refining the raw dataset, they will use the NAVOCEANO Bathymetry and Hydrographic Processing Package (BHPP) tools to generate grid datasets. Using command line utilities developed in the AQS-20 RTP, the grid datasets are then submitted to the NAVOCEANO TEDServices Gateway as an official NAVOCEANO bathymetry product. Once in the TEDServices system, the remote survey platform can automatically retrieve the new bathymetry grid and use the dataset in subsequent processing. The automatic download of grids from TEDServices is made possible by the data ordering capabilities in TEDServices which allow a remote Gateway to be configured to synchronize itself with the datasets available on a remote server for a particular datatype. The automatic subscription features are integrated into the SeaBED DM application using interactive dialog windows.

It is also important to note that MEDAL developers are in the final stages of implementing a new API for retrieving data directly from the TEDServices system into MEDAL. Currently, a prototype MEDAL release can retrieve some datatypes from the TEDServices system but not the bathymetry grids generated in the AQS-20 RTP. In the future, the MEDAL system will expand this API to provide the ability to retrieve bathymetry and sediment information directly from the TEDServices system. Then, MEDAL will have access to the datasets from remote BMW/SeaBED platforms and the official NAVOCEANO Gateway.

8. DEMONSTRATIONS

Three demonstrations of the end-to-end capability are planned for FY05. Executed in December 2004, the initial demonstration is a representative simulation that shows the connectivity and functionality using previous collected raw AQS-20 Engineering Development Model (EDM) data with other overlapping historical datasets south of Panama City. In this demonstration, the datasets were processed and fused in a laboratory at NAVOCEANO, and placed locally in the GDBV-D and remotely on a TEDServices Gateway. Output formats were successfully ingested into a MEDAL installation using MEDAL's ftp interface. In addition, NAVOCEANO NCW "reachback" capabilities were demonstrated by sending a processed dataset (in the Generic Sensor Format) to the NAVOCEANO Code N4 (Hydrography) for Quality Assurance, grid generation, and distribution of the official NAVOCEANO edited grid through TEDServices subscription services. From the BMW, the official NAVOCEANO grid was imported into the SeaBED DM for subsequent analysis.

The second demonstration will use land-based MH-53 flights with the AQS-20 EDM flown out of Panama City with the databases and servers set up in hangar and laboratory areas on site. Procedures and processing times will be established in this demonstration. The final demonstration will be conducted at sea showcasing the end-to-end delivery of TTS data from sensor to TDA. This demonstration will use the HSV-X in an MCM command ship role during the summer of 2005.

9. TRANSITIONS

After successful completion of the demonstrations, environmental data extraction and fusion software will be incorporated into the operational BMW. The BMW is currently maintained by NAVOCEANO and is used by Bottom Mapping Teams in theatre to provide environmental information for MIW operations.

10. CONCLUSION

In light of prior TTS developments where the focus has been on the extraction of environment data, the AQS-20 RTP demonstrates the advantages of TTS technologies in a new light. The AQS-20 RTP is a unique approach to TTS technologies in which the primary focus is on efficiently connecting the tactical sensor to the ultimate users of the new datasets: TDAs and models. From the AQS-20 RTP, it is clear that TTS systems will enable: optimized sensor performance, on-scene alteration of tactics and plans, battle group prepositions in near real-time, and long term updates of the Navy standard databases on a global scale.[8]

It is important to understand that organic TTS data collection and assimilation is not intended to replace the high-quality, scientific survey efforts that have been conducted by NAVOCEANO for many years. Instead, TTS systems are intended to augment the measurements and databases that exist in denied areas or in other areas where either lack of data or inadequate data results hinders precision planning and execution of operations in support of Sea Power 21 goals.[8]

The AQS-20 RTP is a complete manifestation of the many goals and visions that have been predicted for the TTS concept. All of the objectives of TTS technology are embodied in the demonstrations and it is evident that organic sensors will greatly enhance the Navy's efficiency in collecting, assimilating, and distributing environmental data. Considering the many systems that have been connected in an interoperable manner, the SeaBED system is a paramount engineering feat. Since the Navy's emphasis on NCW is relatively new, several of the operational bottom mapping systems were not designed for use in an architecture where the principle thrust is data sharing. In spite of these and other complex challenges, the SeaBED system demonstrates the possibilities of TTS systems with minimal impact on the current operational systems. Therefore, the AQS-20 RTP provides a substantial working model of a TTS architecture that is fully connected from sensor to processing and assimilation algorithms to local and global users alike.

11. ACKNOWLEDGEMENTS

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